

layer, having different compositions can also be used. Also in the embodiment, although the structure of the layer was described as a rather simple double hetero (DH) structure, other structures such as, for example, a quantum well structure may also be used. Various device structures other than the above-mentioned broad-stripe type may also be adopted. Furthermore, although a GaInNAs layer was described as a active layer, GaInNAs alloys comprised of either aluminum or phosphorus may also be used as long as nitrogen and arsenic are simultaneously included in the alloy.

Also in this embodiment, the device has better temperature characteristics than that of GaInPAs which is conventionally used for the relatively long wavelength region, and also has a higher light power output, as aforementioned. As a result, fabrications of laser devices benign to human eyes, become feasible, which are used for the telecommunication, ranging, and free-space communication. These lasers can be economically operated without auxiliary circuits for automatic power and/or temperature control, for example.

### Example 3

Although, there was described in embodiment 2, a light emitting device which was constituted of GaInNAs active layer and had a double heterostructure, a light emitting device comprising also a GaInNAs active layer and having the homo-junction or single heterostructure, may also be fabricated. FIG. 8 represents a sectional view of a light emitting device having a homo-junction structure of embodiment 3.

The light emitting device comprises, an n-GaInNAs layer 72, a p-GaInNAs layer 73, and a p-GaAs contact layer 74, disposed by MOCVD method on an n-GaAs substrate 71 in the order stated. Additionally provided for the device were a positive electrode 75 on the p-GaAs contact layer 74 and a negative electrode 76 on the rear side of the n-GaAs substrate 71.

The present GaInNAs layer was grown so as to be lattice-matched to the GaAs lattice under the same conditions as those adopted in embodiment 1. Also in the present growth, an  $\text{AsH}_3$  partial pressure was 50 Pa which was higher than that for the conventional growth. This resulted in a GaInNAs active layer with fewer group V vacancies than those in conventionally grown layers and with a higher photoluminescence efficiency.

The control of conductive properties and charge concentration was typically carried out by using dopants such as selenium for n-type, and zinc for p-type. Referring to FIG. 8, for example, selenium was used as an n-type dopant for the n-GaInNAs layer 72, and zinc was used as a p-type dopant for the p-GaInNAs layer 73. As source materials of these dopants, hydrogen selenide for selenium, and dimethylzinc (DMZn) or diethylzinc (DEZn) for zinc were used. Doping efficiencies for these dopants were found satisfactory.

It is generally known that an GaInNAs active layer for DH laser is undoped and, therefore, control of dopants is not necessary. (An exception may be cited here, for the DH LED application, an GaInNAs active layer is often doped, thereby necessitating dopant control.) However, for LEDs having a homo-junction structure such as described in this embodiment, control of carrier concentrations and a conductive type has to be made, thereby necessitating control of both n-type and p-type dopants. In the present embodiment, selenium and zinc were used for the n-type and p-type dopant, respectively.

It may also be possible to add dopants into a GaInNAs active layer of a DH laser, such as selenium or zinc, for example. This results in a decrease in threshold current for

the light emission, since a carrier concentration in the active layer increases, a width of a depletion layer decreases, and a recombination current decreases.

In addition, a bandgap energy of GaInNAs layers is smaller than that of GaAs, as aforementioned. Because of the smaller bandgap energy, the resultant emission from the GaInNAs layers is transparent for GaAs substrates and GaAs contact layers. Therefore, light emitting devices such as described in the above embodiments 1 and 2 may preferably be used as vertical cavity surface emitting lasers (VCSELs) and surface emitting LEDs.

In addition to above-mentioned selenium and zinc, dopants such as beryllium, magnesium, carbon, silicon, germanium, tin, sulfur, or tellurium may also be used. However, since silicon, carbon, germanium and tin are amphoteric, these dopants have the possibility of occupying either group-III or group-V site to complete the charge compensation. Since neither selenium (group VI) nor zinc (group II) is amphoteric, the above-mentioned difficulty can be obviated. Therefore, it is preferred to use group VI dopants such as selenium for n-type and group II dopants such as zinc for p-type, for example.

In addition, a p-n junction can be formed by diffusing appropriate dopants. Furthermore, although the GaInNAs layer was described as an active layer, GaInNAs layers comprised of both of, or either of aluminum or phosphorus may also be used as long as nitrogen and arsenic are simultaneously included in the alloy.

As described above, nitrogen-containing III-V alloy semiconductors can be grown without increasing concentrations of arsenic vacancies, thereby leading to the fabrication of epitaxial wafers and light emitting devices with noble features, using the wafers. For example, there can be preferably fabricated light emitting devices with better temperature characteristics than that of GaInPAs which has conventionally been used in the long wavelength region, and also have a high light power output.

In addition, the uses of the present nitrogen-containing III-V alloy semiconductors are not limited to the above-mentioned light emitting devices, and photodetecting devices such as, for example, photodiodes of excellent characteristics also may preferably be fabricated.

Additional modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

What is claimed as new and desired to be secured by Letters Patent if the United States is:

1. A method for growing at least one layer of III-V alloy semiconductor on a semiconductor substrate, and including at least nitrogen and arsenic simultaneously, comprising forming said alloy semiconductor by a conventional low pressure MOCVD method, using a nitrogen containing organic compound as a source material for nitrogen and  $\text{AsH}_3$  for arsenic, wherein said III-V alloy semiconductor comprises GaInNAs.

2. The method according to claim 1, wherein said semiconductor substrate comprises GaAs.

3. The method according to claim 1, wherein said nitrogen containing organic compound is selected from the group consisting of dimethylhydrazine and tertiary butyl amine.

4. The method according to claim 1, further comprising controlling conductive properties of, and carrier concentrations in said alloy semiconductor by adding a dopant, wherein said dopant is selected from the group consisting of beryllium, magnesium, zinc, carbon, silicon, germanium, tin, sulfur, tellurium, and selenium.

5. The method for growing at least one layer of III-V alloy semiconductor on a GaAs substrate, and including at least

nitrogen and arsenic simultaneously, comprising forming said alloy semiconductor by a conventional low pressure MOCVD method under specified conditions of temperatures and pressures, using a nitrogen containing organic compound as a source material for nitrogen and  $\text{AsH}_3$  for arsenic, wherein said III-V alloy semiconductor comprises GaInNAs.

6. The method according to claim 5, wherein said specified conditions are a partial pressure of said  $\text{AsH}_3$  in a reactor of equal to or more than 2 Pa and a temperature of said semiconductor substrate of equal to or more than 550° C.

7. The method according to claim 5, wherein said specified conditions are a partial pressure of said  $\text{AsH}_3$  in a reactor of equal to or more than 10 Pa and a temperature of said semiconductor substrate of equal to or more than 600° C.

8. The method according to claim 5, wherein said nitrogen containing organic compound is selected from the group consisting of dimethylhydrazine and tertiary butyl amine.

9. The method according to claim 5, further comprising controlling conductive properties of, and carrier concentrations in said alloy semiconductor by adding a dopant, wherein said dopant is selected from the group consisting of beryllium, magnesium, zinc, carbon, silicon, germanium, tin, sulfur, tellurium, and selenium.

10. A method for growing at least one layer of III-V alloy semiconductor on a GaAs substrate, and including at least nitrogen and arsenic simultaneously, comprising:

forming said alloy semiconductor by a conventional low pressure MOCVD method, using a nitrogen containing organic compound as a source material for nitrogen and  $\text{AsH}_3$  for arsenic, under conditions such as a partial pressure of said  $\text{AsH}_3$  in a reactor of equal to or more than 2 Pa and a temperature of said semiconductor substrate of equal to or more than 550° C., wherein said III-V alloy semiconductor comprises GaInNAs.

11. The method according to claim 10, wherein said nitrogen containing organic compound is selected from the group consisting of dimethylhydrazine and tertiary butyl amine.

12. The method according to claim 10, further comprising:

controlling conductive properties of, and carrier concentrations in said alloy semiconductor by adding a dopant, wherein said dopant is selected from the group consisting of selenium, zinc, and magnesium.

13. A method for growing at least one layer of III-V alloy semiconductor on a GaAs substrate, and including at least nitrogen and arsenic simultaneously, comprising:

forming said alloy semiconductor by a conventional low pressure MOCVD method using a nitrogen containing organic compound as a source material for nitrogen and  $\text{AsH}_3$  for arsenic, under conditions such as a partial pressure of said  $\text{AsH}_3$  in a reactor of equal to or more than 10 Pa and a temperature of said semiconductor substrate of equal to or more than 600° C., wherein said III-V alloy semiconductor comprises GaInNAs.

14. The method according to claim 13, wherein said nitrogen containing organic compound as said source mate-

rial for nitrogen is selected from the group consisting of dimethylhydrazine and tertiary butyl amine.

15. The method according to claim 13, further comprising:

controlling conductive properties of, and carrier concentrations in said alloy semiconductor by adding a dopant, wherein said dopant is selected from the group consisting of beryllium, magnesium, zinc, carbon, silicon, germanium, tin, sulfur, tellurium, and selenium.

16. A method for fabricating a semiconductor device, having at least one layer of a III-V alloy semiconductor on a GaAs substrate, comprised of a plurality of group V elements including at least nitrogen and arsenic simultaneously, comprising:

forming said alloy semiconductor by a conventional low pressure MOCVD method, using a nitrogen containing organic compounds as a source material for nitrogen and  $\text{AsH}_3$  for arsenic, under conditions such as a partial pressure of said  $\text{AsH}_3$  in a reactor of equal to or more than 2 Pa and a temperature of said semiconductor substrate of equal to or more than 550° C., wherein said III-V alloy semiconductor comprises GaInNAs.

17. The method according to claim 16, wherein said nitrogen containing organic compound is selected from the group consisting of dimethylhydrazine and tertiary butyl amine.

18. The method according to claim 16, further comprising:

controlling conductive properties of, and carrier concentrations in said semiconductors by adding a dopant, wherein said dopant is selected from the group consisting of beryllium, magnesium, zinc, carbon, silicon, germanium, tin, sulfur, tellurium, and selenium.

19. A method for fabricating a semiconductor device, having at least one layer of a III-V alloy semiconductor on a GaAs substrate, comprised of a plurality of group V elements including at least nitrogen and arsenic simultaneously, comprising:

forming said alloy semiconductor by a conventional low pressure MOCVD method using a nitrogen containing organic compound as a source material for nitrogen and  $\text{AsH}_3$  for arsenic, under conditions such as a partial pressure of said  $\text{AsH}_3$  in a reactor of equal to or more than 10 Pa and a temperature of said semiconductor substrate of equal to or more than 600° C.

20. The method according to claim 19, wherein said nitrogen containing organic compound is selected from the group consisting of dimethylhydrazine and tertiary butyl amine.

21. The method according to claim 19, further comprising:

controlling conductive properties of, and carrier concentrations in said alloy semiconductor by adding a dopant, wherein said dopant is selected from the group consisting of beryllium, magnesium, zinc, carbon, silicon, germanium, tin, sulfur, tellurium, and selenium.

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